A Wireless First Responder Handheld Device for Rapid Triage, Patient Assessment and Documentation during Mass Casualty Incidents

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Medical care at mass casualty incidents and disasters requires rapid patient triage and assessment, acute care and disposition often in the setting of overwhelming numbers of victims, limited time, and little resources. Current systems rely on a paper triage tag on which rescuers and medical providers mark the patient's triage status and record limited information on injuries and treatments administered in the field. In this manuscript, we describe the design, development and deployment of a wireless handheld device with an electronic medical record (EMR) for use by rescuers responding to mass casualty incidents (MCIs) and disasters. The components of this device, the WIISARD First Responder (WFR), includes a personal digital assistant (PDA) with 802.11 wireless transmission capabilities, microprocessor and non-volatile memory, and a unique EMR software that replicates the rapidity and ease of use of the standard paper triage tag. WFR also expands its functionality by recording real-time medical data electronically for simultaneous access by rescuers, mid-level providers and incident commanders on and off the disaster site. WFR is a part of the Wireless Information System for Medical Response in Disasters (WIISARD) architecture.

INTRODUCTION

Medical first responders at a disaster site or large natural catastrophe often must provide care under immense time pressure, in a setting of overwhelming numbers of casualties, limited resources, fractured communication systems, and unanticipated chaos and adversity. Medical care in such mass casuality incidents (MCIs) is prioritized to initial patient triage, acute care as dictated by the number and types of injuries and available resources (both human and material), and rapid patient disposition (to the hospital, morgue, field casualty collection sites or other holding areas). Accurate, accessible and timely information on the victims, their injuries and status, the care provided in the field (including decontamination), and ultimate patient disposition are critical to the success and organization of the overall response to such a disaster.

Currently for MCIs, providers rely on paper triage tags to record critical victim data and information

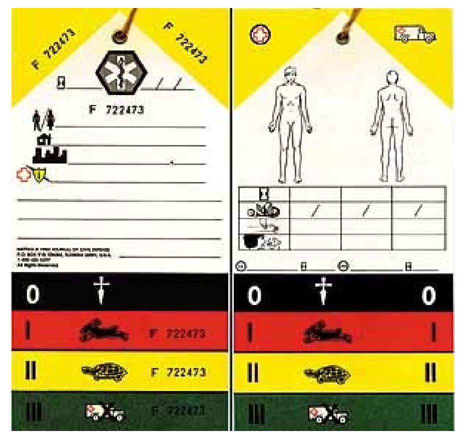


Figure 1. Example of a paper triage tag.

including triage status, medical care, and patient disposition. These paper tags have the primary advantage of ease of use and rapid deployability. These tags rely on a simplified triage system (START – Simple Triage And Rapid Treatment) to quickly determine patient status, condition and priorities for care and disposition.(1,2) The tags are secured directly to the patient (by string either around the wrist or neck) and have tear-off tabs to identify patients according to triage category to aid in the processing of victims.:*Immediate*, *Delayed*, *Minor*, and *Comfort-Care or Dead*.(3,4) (Figure 1).

In additional to recording the severity of injury, triage tags serve as the equivalent of hospital identification bracelets and are numbered and barcoded to provide a unique identifier.(3) The tags also have space for writing medical information and serve as the as the primary means of documentation of field care, communication and information transfer between the field and hospital.

However, tags have well-known limitations as a form of medical documentation. The space for recording data is limited. The "tear off" format of tags only allows unidirectional changes in patient condition (worsening). The tags are not weather resistant, and are easily marred or destroyed. Moreover, the tag is a static and disconnected information repository. Real-time information regarding victims and their status is critical to the overall management of field medical care. Medical command must coordinate timely information on the number of casualties and their needs with the known availability of resources, such as on-scene providers, ambulance locations, and area hospital capacities. Real-time information is also critical to determining the appropriate patient destination, depending on the type of injuries and the capabilities of the receiving facilities. (5,6)

This "sequential interdependence" highlights the importance of transfer of that information in the disaster setting. Actions in the field (such as triage, transport and treatment of victims) ultimately impact hospital resources and capabilities. Real-time information on hospital and health care resources has an important impact on disaster response management and field care of victims. Yet this information is often not available and is hampered by the lack of a comprehensive communication and information system at the disaster scene.(7,8,9)

This manuscript describes the design, development and test implementation of a wireless handheld provider device for use in the MCI field setting to rapidly record and patient triage, status, medical care and disposition of victims on the scene. The development of these devices is a part of the Wireless Internet Information System for Medical Response in Disasters (WIISARD) project funded by the National Library of Medicicne's Internet II Research Program.

WIISARD FIRST RESPONDER DESIGN

WIISARD: WIISARD will provide emergency personnel and disaster command centers with medical data to track and monitor the condition of hundreds to thousands of victims on a moment-to-moment basis, over a period of hours to days during a disaster of MCI event. The focus of WIISARD is on the use of 802.11 (WiFi) wireless based technologies to coordinate and enhance care of mass casualties in a terrorist attack or natural disaster. The key components of the WIISARD system include:

- WIISARD First Responder (WFR) handheld wireless devices to electronically record and document patient status, medical care and disposition on scene;
- Electronic, intelligent patient monitoring devices tracking victim identification and location;
- Management systems accessing data and displaying victim, provider and scene information for responders, mid-level scene managers and overall incident commanders;
- CalMesh nodes, mobile, rapidly deployable wireless access points with integrated GPS, mesh and ad hoc networking, to create the communications infrastructure for the site;
- Integrated software systems operating concurrently through all layers in all the various devices serving to enhance the situational awareness of first responders, recording of medical data, aiding in the monitoring of victims, and facilitating communication of data to hospitals.

Scenario of use

WIISARD is designed for use in a MCI event resulting from a weapon of mass destruction, natural disaster or industrial accident. The event could have as many as several thousand victims in various conditions from walking-wounded through deceased. Because of transportation bottlenecks or contamination issues medical care would have to be afforded to the victims at the scene or nearby.

Upon arriving in a Mobile Command Post at the scene, CalMesh nodes would be deployed throughout the site to create a communications bubble over the area. First responders would move throughout the site and each victim would be tagged. Providers would rapidly enter information on each victim electronically via the WFR handheld device. This data would include victim identification, triage status, condition, and treatment. The data would be routed via the CalMesh nodes to the Mobile Command Post where it is processed, stored, relayed to the Internet, and moved back to devices on the field. As a result, data on casualities would be accessible immediately within the WIISARD database for operational use by other providers, scene responders, incident commanders and even receiving hospitals.

The WFR is a critical component of the WIISARD system providing the essential interface by which responders record data on victims and casualties at the scene electronically. Data is then stored and archived on the WIISARD system available and accessible to all other facets of the disaster response.

Key design features for the WFR include:

- Rugged personal digital assistant device (PDA) that can tolerate extreme conditions during use;
- Small handheld device with large screens for ease of use in the field setting;
- 802.11 wireless communication and ad-hoc network capability
- Secure data communications via Internet protocols
- EMR software that is simple, intuitive and easy to use for first responders under the difficult conditions of disaster response;
- Screens with visible displays in daylight;
- Battery life of at least 4-6 hours;

• Self-diagnosing and remote software upgrading;

DEVELOPMENT

WFR development included input from key stakeholders including Emergency Medical Service paramedics and first responders (San Diego City Fire and Life Safety Services), as well as specialist responders to mass casualty and WMD events (San Diego County Metropolitan Medical Strike Team). The PDA platform selected was the HP iPAQ 5555 handheld device (Figure 2). Augmentations included:

Figure 2: WFR PDA

- Intel X-Scale PXA255 400MHz processor with 128 MB RAM and 64 MB of flash memory.
- 802.11 wireless connectivity
- Barcode reader and class II scanner

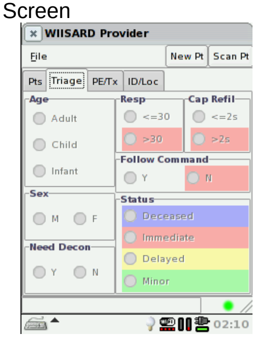
Linux-based EMR software was developed to replicate and expand the functionality of the current MCI paper triage tag and medical documentation methods. Linux version 0.8.3 with GPE 2.7 (GPE Palmtop Enviroment). The front end is designed using GTK+(GIMP toolkit) 2.4 and the back-end is called WIISARD2.Multiple screens were developed to allow easy navigation and documentation in the field setting of the following:

- Patient Identification
- START Triage and triage acuity level
- Treatment and medications administered
- Disposition status

The EMR utilized methods to simplify documentation for rapidity, navigability and ease of use:

- Barcodes and scanning were utilized for rapid "logging in" of patient tags, as well documentation of medication and treatment administration;
- Simplified "point-and-click" systems based on existing START triage algorithms were developed;

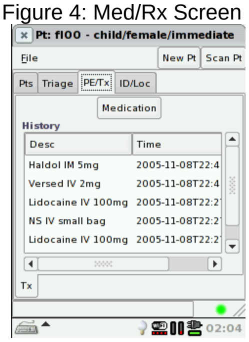
Figure 3: START Triage Screen



- Drop-down and pick lists were designed to insure ease of use, as well as accuracy of data input.

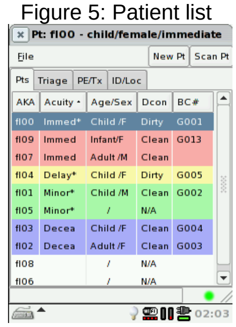
The initial triage screen was designed for rapid, simple, and accurate data entry when a new victim is encountered and tagged. The providers scans the patient ID tag barcode with the WFR and the initial START triage screen pops-up. Based on existing START algorithms, data is entered with a simple touch screen including demographics (Adult/Child/Infant), respiratory rate, capillary refill, mental status (follows commands). Data on these elements determines triage status automatically based on these existing algorithms. The screen also includes other data critical to the response, namely decontamination status of the individual and their primary injuries (Figure 3).

Figure 4: Med/Rx Screen



The medication-treatment screen records all medications and treatments administered in the field. The EMR utilizes both barcode scanning of medications as well as a drop-down menu for treatments, allowing manual as well as automated rapid entry. For medications, dose, route, unit and time are recorded. The system includes adjustments for pediatric dosing (Figure 4).

Figure 5: Patient list



In addition, a provider patient list screen was developed allowing a concise list of all patients under the care of a given provider. To determine treatment and disposition priorities the list can be rapidly sorted by patient, triage status acuity, decontamination status, or disposition (Figure 5).

IMPLEMENTATION & TESTING

Prototype WFRs were implemented with 2 testbed settings: first, devices were utilized in a controlled mock event with simulated clinical

patient scenarios to be entered into the WFR by WIISARD technical staff; second, the devices we then distributed to actual first responders as a part of a large scale MCI drill with 100 actors simulating victims of a terrorist disaster incident.

Testbed #1: Functionality Test Implementation

Testbed #1 was designed to evaluate the functionality of the WFR and the WIISARD system under a mock event simulated by WIISARD technical staff. In this testbed, 32 patient scenarios were created and attached to barcoded tags. WIISARD staff established an adhoc 802.11 mesh network in an outdoor setting of approximately 200 yards in diameter and the tags were distributed throughout this area. Staff utilized the WFR to enter patient data under the triage screen with acuity status determined automatically by the START triage algorithm. The patient scenarios were evaluated by physicians unaware of the WFR who determined acuity status based on their own assessment of the scenario. Data obtained with the WFR was compared with the actual number of victim scenarios as well as the physician evaluation.

Overall, 32 of 32 patient scenarios were successfully logged by the three individuals operating the WFR. Acuity status (Immediate, Delayed, Minor, Dead) were in agreement between the WFR and MD evaluation in 25 of 32 scenarios. In the 7 cases where there was disagreement, the WFR acuity status was one step higher than the MD evaluation (6 cases were coded as Immediate by the WFR compared to Delayed by MD; and 1 case Delayed compared to Minor respectively).

Testbed #2: Field Drill Implementation

An operational field test of the WFR was conducted as a part of the WIISARD system in a large scale MCI incident involving a simulated terrorist chemical HAZMAT and blast injury disaster (Operation Fairgrounds, San Diego County, November 2005). This large scale drill involved 100 actors simulating victims, over 20 responding law, fire and EMS agencies, and hundreds of first responders, scene managers, and incident commanders. Fifteen WFR devices were deployed to initial EMS and fire personnel responsible for triaging, treating and determining disposition of the simulated victims on scene. Responders had little or no training with the device, but WIISARD staff were on scene to provide support (Figure 6).

Overall, responders utilized the WFR to triage and log 97 unique patient encounters in the field setting out of the 100 total victims simulated. The pre-designed scenarios estimated that of the 100 simulated victims 37 would be Immediate; 39 Delayed; and 25 Minor. Of the 97 unique WFR patient encounters, 42 were coded as Immediate, 29 Delayed, 7 Minor, 6 Dead, and 13 not determined. The average time for the first responder to initiate and complete the WFR triage screen was 40 seconds (range up to 4 minutes). All patient data logged was automatically transmitted to an active WIISARD database that allowed simultaneous access and display of patient logs.

DISCUSSION

The advent of computer miniaturization, PDAs and wireless technologies have allowed the development of mobile data acquisition and monitoring devices. The WIISARD First Responder represents a initial prototype handheld PDA EMR designed specifically for medical care at a disaster site. The challenges of tracking victims and recording triage and disposition are well known as seen from the design group from Jonhs Hopkins University.(9)(12) Because of these challenges, first responder agencies rely on simple triage tags, paper and pen to record fieldl data despite the growing use of information technologies throughout the healthcare setting.(14)(15)

We designed the WFR to replicate as much as possible the simplicity and ease of use of paper tags, but with the functional advantages of electronically recorded data, automated features including barcode scanning, and wireless data transmission to a real-time patient database accessible to multiple users simultaneously. In a full scale functional disaster drill, we found first responders with little or no training on the device, readily adapting and using the device with little difficulty, and with a remarkable alacrity particularly when initially triaging patients. During both tests of the WFR, providers accurately logged and entered most victims into the WIISARD database. However, the determination of triage acuity by the WFR's automated START triage algorithm occasional did not correspond with planned or determined simulated victim counts. It should be noted though that determination of triage status was left to clinical judgment by both MD reviewers (testbed #1) and event planners (testbed #2) and it is difficult to determine if disagreement in triage classification reflected an inherent flaw with the WFR and its EMR or more likely a simple difference in clinical opinion. Other studies have noted wide variation with the START triage.(16) It is interesting to note, however, that the WFR EMR START triage tended to increase the severity of triage classification.

Handheld PDAs have been explored in the military to digitally record field care. The Tactical Medical Coordination System (TacMedCS) uses RFID technology embedded in the military ID tag to store data and track position. The handheld device tracks and stores vital patient information.(17)(18) The Battlefield Medical Information System-Joint (BMIST-J) is used by the Army. This application uses the handheld device to record, store, retrieve and transmit essential elements which can later be synchronized with host computers.(19) The Electronic Field Medical Chart has been developed as just such a field record integrated with the latest generation of mobile computing devices.(10)(13) On the civilian level, the St. Louis Metropolitan Medical Response System recently tested an emergency patient-tracking system combining bar code identification with PDA data entry, connnected by cellular and 802.11 interfaces.(11)

The WFR also utilizes 802.11 wireless connectivity as a part of the larger WIISARD system for medical response to MCI and disasters. The WFR functions under an ad-hoc mesh network established by WIISARD at the disaster site. As such, the WFR has the potential for other benefits for disaster responders. The device can serve as an additional communication tool between rescuers and incident managers, sending alerts and messages via 802 wireless transmissions. Moreover, just as patient data is recorded and transmitted from the WFR to incident commanders via the database, resource data including ambulance and hospital availabilities can be transmitted or made accessible to the WFR to notify responders taking care of patients in the field. The WFR can utilize geopositioning and ad hoc localizing technologies to improve not only patient, but also provider location tracking and improved responder safety. Finally, the wireless WFR device has the potential to provide additional informatics support to disaster responders thru its Internet connectivity.

LESSONS LEARNED

Testbed#2 was used to test both the responder ‘s workflow as well as the WFR workflow. Since this was a drill in a simi-controlled enviroment we have learned that in a real event will be less organized and that we are unsure how a tool such as the WFR will not only aid in the overall tracking of victims but possibly better organize the first responder. Also we have learned that this tool must work in a disconnected network setting and the the first reponders must both be unaware of the disconnect but also feel comfortable working in this type of information eviroment.

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REFERENCES

1. Schultz CH, Koenig KL, Noji EK. A medical disaster response to reduce immediate mortality after an earthquake. N Engl J Med 1996;334(7):438-44.
2. Garner A, Lee A, Harrison K, Schultz CH. Comparative analysis of multiple-casualty incident triage algorithms. Ann Emerg Med 2001;38:541-8.
3. Garner A. Documentation and tagging of casualties in multiple casualty incidents. Emerg Med (Fremantle) 2003;15(5-6):475-9.
4. Cohen E. A better mousetrap. What makes up the "perfect" triage tag? Jems 1983;8(7):30-2.
5. Teich JM, Wagner MM, Mackenzie CF, Schafer KO. The informatics response in disaster, terrorism, and war. J Am Med Inform Assoc 2002;9(2):97-104.
6. Plischke M, Wolf KH, Lison T, Pretschner DP. Telemedical support of prehospital emergency care in mass casualty incidents. Eur J Med Res 1999;4(9):394-8.
7. Mattox K. The World Trade Center attack. Disaster preparedness: health care is ready, but is the bureaucracy? Crit Care 2001;5(6):323-5.
8. Lee WH, Chiu TF, Ng CJ, Chen JC. Emergency medical preparedness and response to a Singapore airliner crash. Acad Emerg Med 2002;9(3):194-8.
9. Chan TC, Killeen J, Griswold W, Lenert L: Information technology and emergency medical care during disasters. Acad Emerg Med 2004; 11:1229-36.
10. Clinical systems integration: electronic medical records: Available at: http://www.saic.com/healthcare/clinical/e-medrec.html. Accessed 3/7/06.
11. Hamilton J: Automated MCI patient tracking: managing mass casualty chaos via the Internet. JEMS 2003;28(4):52-12.Gao T, Greenspan D, Welsh M, Juang R, Alm A: Vital Sign Monitoring and Patient Tracking over a wireless network. Proceedings of the 27th Annual International Conference of the IEEE EMBS, Shanghi Sept 2005
13.Mobile IRIS by iomedix corporation. Available at: http://www.iomedex.com.
14.Risavi BL, Salen PN, Heller MB, Arcona S: A two hour intervention using START improves prehospital triage of mass casualty incidents. Prehosp Emerg Care. 2001 ;5(2):197-9.
15.Benson M, Koenig KL, Schultz CH. Disaster triage: START, then SAVE-a new method of dynamic triage for victims of a catastrophic earthquake. Prehospital Disaster Med. 1996 Apr-Jun;11(2):117-24.
16.Garner A, Lee, A, Harrison K, Schultz CH: Comparative analysis of multiple casualty incident triage algorithms. Ann Emerg Med 2001;**38**:541–8.
17.TacMedCS (Tactical Medical Coordination System). Available at: http://www.namrl.navy.mil/clinical/projects/tacmedcs.htm
18.Davis J, Ryan D: Plastic tag may help corpsmen save Marine lives. Available at: http://www.dcmilitary.com/navy/journal/6_30/national_news/8983-1.html
19.Battlefield Medical Information System Telemedicine -joint (BMIST-J).
Available at: https://www.mc4.army.mil/BMIST-J.asp